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ABSTRACT

This study compared the biomechanical support offered by eight presently marketed sports bras for small-, medium-, and large-breasted women while jogging. Fifty-nine subjects were filmed while jogging on a treadmill in each of the bras and in the nude condition. The vertical displacement of the breast relative to the body during one average running stride was calculated for each condition. An ANOVA and pairwise difference procedures revealed significant differences between the D cup size group and each of the remaining three cup size groups in the nude condition. In addition a two-way repeated measure ANCOVA indicated significant pairwise differences among the bras; both within each cup size group, and within the group as a whole. Implications for future biomechanical breast research and sports bra design are discussed. (Author/JD)

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The Biomechanical Support of Eight Selected Sports Bras
for Small, Medium and Large Breasted Women While Jogging

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Running Head: Bra Biomechanics

Date: April 18, 1986

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Abstract

This study compared the biomechanical support offered by eight presently marketed sports bras for small, medium, and large breasted women while jogging. Fifty-nine subjects (14 A, 16 B, 15 C & 14 D bra cup size groups) were filmed while jogging on a treadmill at 6 mph in each of the bras and in the nude condition. The vertical displacement of the breast relative to the body during one average running stride was calculated for each condition. An ANOVA and pairwise difference procedures revealed significant ($p < .05$) differences between the D cup size group and each of the remaining three cup size groups in the nude condition. In addition a two-way repeated measure ANCOVA (using the mean displacement in the nude condition for each group as the co-variate) indicated significant pairwise differences among the bras; both within each cup size group, and within the group as a whole. Implications for future biomechanical breast research and sports bra design were discussed.

The Biomechanical Support of Eight Selected Sports Bras for
Small, Medium, and Large Breasted Women While Jogging¹

Since the advent of the women's movement in the 1960's and the accompanying federal legislation in the 1970's, which mandated equal access to athletic opportunities for women, female participation in sports has increased dramatically (Oglesby, 1978). In addition, increasing numbers of non-athletes—members of the general population—are engaging in regular non-competitive but strenuous exercise (Gerber, Felshin, Berlin & Wyrick, 1974).

To accomodate the exercise trend, sports equipment and apparel have been designed especially for women. Included are several types of sports bras. Foundation garment manufacturers have tried to capitalize on the sports bra market: although a number of bras are currently marketed as sports bras, few have been designed using data from empirical studies of the biomechanics of breast motion. Moreover, most existing research on sports bras has been conducted on athletes, who constitute only a small percentage of active women. Breast sizes of athletes tend to be smaller than those of the general population and therefore, they have fewer problems with bras. The needs of large

¹ This research was supported by a Utah State University Faculty Research Grant, from the office of the Vice President for Research, Logan, Utah. The authors wish to extend special thanks to Jim Shaver for reviewing the manuscript, and Maria Norton for data analysis consultation.

breasted. active women have not yet been seriously addressed.

The current leaders in women's sports advocate involvement of all women in an active lifestyle, regardless of their size, shape or age. The emphasis is on fitness, positive self-image, and enjoyment rather than on weight loss, which has often been the focus of recreation programs ("Text of Draft Resolutions," 1983). In order to encourage women of all ages to become involved in a healthier, more active lifestyle, the barriers of physical discomfort, and/or self-consciousness need to be lowered. More adequate means of controlling breast motion through better bra design may be an important part of this effort. This study examined the biomechanical support offered small, medium and large breasted women by eight presently marketed sports bras while jogging. Design characteristics of the bras were related to the empirical findings.

Prior Research

The limited body of literature pertaining to breast motion and sports bra design generally falls into two categories: informal survey debate over whether specially designed sports bras are necessary and, if so, what design types are best; and, biomechanical studies of breast motion and bra design. The majority of studies in both categories support the recommendation that athletes ought to wear special sports bras to minimize breast injury and soreness during strenuous activity and to help prevent sagging later in life (Haycock, Shierman, & Gillette, 1978; Bayne, 1968; Haycock, 1978; Shuster, 1979; Gehlsen & Albohm, 1980). Studies that have addressed women's

needs in sports bras include the complaints about bras registered in the study by Haycock and associates (1978) in which the members of 115 U.S. college and university physical education departments and trainers of four women's football teams were surveyed in regard to abrasive metallic or plastic parts, or to allergic reactions to the materials in the bras. All-elastic bras were reported to irritate the skin, and basketball and volleyball players noted slipping shoulder straps and bras that "rode up." Based on research compiled from three different studies, Haycock (1978) indicated that a good sports bra should meet the following criteria: (1) provides good upward support; (2) limits motion of the breast relative to the body; (3) is made of a material that is absorptive, non-allergenic, non-abrasive, and mostly non-elastic, and (4) has fasteners well covered to prevent abrasion to the skin or to other players; (5) utilizes straps that are wide, non-elastic and designed so that they do not slip off the shoulders; (6) makes provision at the base of the bra to prevent "riding-up" of the bra over the breast; and, (7) provides a pocket inside the bra for placement of protective padding.

In a poll conducted by Sportsmedicine (Women marathoners describe their bra needs," 1977), 27 national marathon finalists indicated the following requirements for sports bras: firm support on the side; no lace, padding or underwires; lots of support; an all elastic back; and a wide variety of sizes. In another study, Hunter and Torgan (1982) questioned 85 intercollegiate athletes about breast pain during sports and about the kinds of bras they used. The women in

this study stated that bras should be inexpensive, easy to care for, available in many sizes, made of absorbent fabric, and constructed with seamless cups and non-irritating straps.

In general, improvements in sports equipment and apparel design have been influenced by surveys and informal polls as well as by biomechanical research, resulting in beneficial changes (Burdett, 1983). To date, however, only two studies have used biomechanical techniques to investigate breast motion with and without support. Haycock (1978) filmed five athletes walking and jogging on a treadmill wearing their own bras, no bras, and wearing specially fitted bras, and the fitted bras markedly restricted both vertical and lateral motion.

Because bra design may influence discomfort, Gehlsen and Albohm (1980) used biomechanical procedures to determine: (1) whether there is a difference in support provided by selected bras, (2) the normal, acceptable range of breast motion for comfort, and (3) the effects of additional binding of the breasts during jogging. An ANOVA utilizing data on forty female athletes showed statistically significant differences among eight selected sports bras in the mean vertical displacement of breasts allowed in relation to the body during one running stride. Gehlsen and Albohm also concluded that the mass of the breast in conjunction with the velocity of movement may be related to discomfort while jogging, and that binding over a bra prevents over 45% of the movement.

Although available sports bras are designed to minimize breast motion during activity, the models vary considerably. Research

conducted on existing models clearly indicates that few bras on the market meet the standards specified by athletes (Haycock, Shierman & Gillette, 1978; Gehlsen & Albohm, 1980). Furthermore, the existing data have been collected on competitive collegiate athletes rather than members of the general population who vary more in age, weight, and breast size.

Method

Objectives

1. To determine and compare the normal range of vertical nude breast movement during jogging (i.e., vertical displacement of the breast relative to the body during one average running stride) for women of small (A cup size), medium (B and C cup sizes), and large (D cup size) breast size.
2. To compare the differences in the biomechanical support provided by eight selected sports bras presently on the market (i.e., the amount of vertical displacement of the breast relative to the body) allowed in small, medium and large breasted women, as well as in the group as a whole.
3. To compare design features of the bras which most restrict vertical breast motion, and those bras which least restrict vertical breast motion, in the group as a whole and within each cup size.

Preliminary Procedures

The subjects (Ss) were volunteer female residents of Cache and Salt Lake Counties, Utah. The 59 Ss were divided into four

experimental groups of approximately 15 according to bra cup size (A cup=small; B cup=medium; C cup=medium/large; and D cup=large). The mean age of the entire group was 31.3 years (range=18-60 years). Forty-two of the Ss had no children, and the remaining 17 Ss had from 1 to 6 children. Of this group of 17 mothers, 11 (18.6% of the total sample) had breastfed their children. The mean physical characteristics of the entire group of Ss, and of each cupsize group (A,B,C,D) are summarized in Table 1. These anthropometric data include: height, weight, percent body fat, chest and breast circumference, and chest depth and width.

Insert Table 1 about here

The Ss first completed a short survey assessing previous sports-related breast injuries and/or breast pain, and current use of specially designed sports bras. The responses for the entire group and for each cup size group are shown in Table 2. Nine of the women (15.3%) had suffered sports-related injuries to the breast. The most common injuries were blows to the breast from equipment or other players, and abrasions from bras.

For the entire group, more than half (55.9%) had experienced sports-related breast pain. Among the 33 women in the entire group who had experienced pain, the most common causes were pain due to excessive breast motion (27.3%) and pain due to pre-menstrual syndrome (51.5%).

Although cup size groups were reasonably similar in incidence of reported pain, the smaller cup size groups complained primarily of pain related to pre-menstrual syndrome, and the larger cup size group complained mostly of pain resulting from excessive motion. It is unusual, however, that fewer larger breasted women (C & D cup) reported exercise-related breast pain, in comparison to smaller breasted women (A & B) cup. This could mean that larger breasted women have adapted to a higher level of discomfort and don't report it as pain, or that there are problems with self-report measures. Out of the entire sample, 18 (30.5%) had used a bra design specifically for sports and exercise prior to the start of the study. Of this group of 18, nine (50%) used the Jogbra brand sports bra. It is interesting to note that only one D cup respondent reported previous sports bra usage. This could be due to limited availability of sports bras in larger sizes.

Insert Table 2 about here

Eight presently marketed sports bras were selected for comparison. They include: Elegant Support (CS), by Creative Support Systems; Jogbra (JB) by Jogbra, Inc.; Lady Duke (LD), by Royal Textile Mills; Sportsbra (CU), by Cupid; Actively Yours (AY), by Actively Yours, Inc.; The Sports Bra by Christina (OC), by Olga; Freedom Frontrunner (OF), by Olga; and Sportsbra (LF), by Lily of France. For a complete description of design characteristics, fabric type, and cost of each style refer to figure 1.

Insert Figure 1 about here

Collection of Biomechanical Support Data

To determine the range of biomechanical breast excursion nude and wearing the eight selected sports bras, the vertical displacement of the breast relative to the body during one average running stride was calculated. The Ss jogged on a treadmill at 6 miles per hour on a flat grade in nine different conditions—first wearing each of the eight selected sports bras, and then nude from the waist up. A body reference mark was placed on the lower sternum to determine vertical displacement of the body in centimeters. The vertical motion of the breast (the net vertical displacement in centimeters) was derived from a second mark placed over the bra at the center of the breast (or over the nipple when nude). The difference between the body displacement and the breast displacement was then calculated. Three rises and falls of the breast were assessed, and the mean of the three vertical displacement values used for analysis.

A 16 mm Photosonics Action Master camera with an internal timing device set at 100 frames per second was used to film the Ss as they jogged on the treadmill. The film was analyzed frame-by-frame on a Lafayette Motion Analyzer.

Analysis and Results

Descriptive statistics were used to summarize and report the

demographic, anthropometric, and survey data (see Tables 1 and 2). To compare the differences in vertical displacement among the A,B,C and D cup size groups in the nude condition, a one-way ANOVA was utilized, along with the Least Squares Difference (LSD) method to determine specific statistically significant differences following significant F's from the ANOVA. To compare differences in the amount of biomechanical support provided by the eight sports bras for each cup size group and the group as a whole, a two-way repeated measures ANCOVA statistical analysis was employed (the Olga Freedom Fronrunner was not available in an A cup size, so this group was only involved in seven conditions). The amount of vertical displacement in the nude condition was used as a covariate to minimize differences due to stride frequency, running style, and age. In addition, an ANCOVA using a combination of 4 different covariates (breast circumference, chest circumference, chest depth and chest width) was utilized to compare differences in the amount of support provided by the seven bras for each cupsize and for the group as a whole. For all of the analyses when a statistically significant F value was found, the LSD method was used to make pairwise comparisons between means for the style pairs.

Displacement in the Nude Condition

A one-way ANOVA for data measuring differences in the amount of vertical displacement of the nude breast among the four cup sizes shows a significant difference between the groups $F(3,55) = 4.73, p < .005$. Results of the LSD method identified significant differences in vertical displacement of the nude breast between the D cup size, and

every other cup size group (A, B, and C cup sizes). There were no statistically significant pairwise differences among the A, B, and C cup sizes (refer to Table 3). Nude displacement accounted for 21% of the shared variance between cupsize groups ($\eta^2 = .21$).

Insert Table 3 about here

Displacement by Bra Styles: Total Group

A two-way repeated measures ANCOVA (with nude displacement as the covariate) indicated that there were significant differences in the amount of vertical displacement allowed by seven different styles worn by the entire group $F(6,330)=18.96$, $p<.000$, and by eight different styles worn by the entire group with the A cup size not included $F(7, 294)= 22.42$, $p<.000$. ANCOVA summary tables and pairwise difference results for these two groups are presented in Tables 4 and 5. Both the CS and LD bras allowed significantly less vertical displacement than each of the other bras in the entire group wearing both 7 or 8 bras. In addition, with the A cup size excluded from the analysis, the OF bra allowed less motion than the JB, CU, AY, OC, and LF bras, and the LF bra was lower in displacement than the OC bra (Table 5). Sixty-two percent ($R^2 = .62$) of the shared variance was accounted for by the variables in the model for the entire group wearing 7 styles and 70% of the share variance was accounted for by the variables in the model for

the entire group wearing 8 styles ($R^2 = .70$).

Insert Tables 4 and 5 about here

Displacement by Bra Styles: Within Cup Size

Analyses of statistically significant pairwise differences for vertical displacement within each cup size are illustrated in Table 6. For the A cup size group, the CS bra allowed less vertical displacement than the CU and LF bras, and the LD allowed less displacement than the CU, AY and LF bras. For the B cup size group, the LD and CS again allowed less motion than several of the other bras (CS < JB, CU, AY, OC, OF and LF; LD < CU, AY, and OC bras). For the C cup size group the CS and LD again allowed less vertical displacement than the JB, CU, AY, OC, OF and LF bras. Additionally, the OF bra allowed less motion than the AY, OC, and LF bras. And, finally, for the D cup size group, the CS bra allowed less motion than all seven of the other bras, and the LD demonstrated less displacement than five of the other bras (JB, CU, OC, AY, and LF). In addition the OF bra allowed less displacement than the JB, CU, AY, and OC bras, and the LF allowed less than the JB and OC bras.

Insert Table 6 about here

It is apparent that both the CS and LD bras were most supportive

in each of the cup size groups, and in the entire group wearing 7 or 8 styles. In addition, in the group wearing 8 styles, the OF and LF were somewhat more supportive than some of the remaining bras in the C and D cup size groups. These data illustrate the nature of the non-significant interactions between cupsize and style for the groups wearing either 7 or 8 styles.

The majority of shared variance was accounted for by person to person variation ($\eta^2 = .44$, Table 5; and $\eta^2 = .32$, Table 4), and nude displacement accounted for only 6% (Table 5); and 4%, (Table 4) respectively of the shared variance among variables. In order to further test the previous findings using different covariates (breast circumference, chest circumference, chest depth and chest width) a final ANCOVA was utilized with the same data. The results of this analysis indicated that there were significant differences in the amount of displacement allowed by seven different styles worn by the entire group with the A cup not included $F(51,6)=18.96$, $p=.000$, (Table 7). Statistically significant pairwise differences are presented in the same table. The results are identical with those found in the analysis in which nude displacement was used as the covariate (rather than the combination of the 4 different covariates used in the present analysis). Again, both the CS and LD allowed significantly less displacement than each of the other bras. The percentage of shared variance accounted for by all the variables in the model is identical with those found in the previous analyses ($R^2 = .62$).

Insert Table 7 about here

Analyses of statistically significant pairwise differences for displacement within cup size are shown in Table 8. For the A cup size both the CS and LD allowed less vertical displacement than CU and LF, and the LD also scored lower than the OC. For the B cup size both the CS and LD allowed less displacement than the CU, AY, and OC, and the CS also scored lower than the JB and LF. In the C cupsize the CS and LD scored identically, allowing less displacement than the JB, CU, AY, OC, and LF. Similar findings are shown for the D cup size. In this group the CS and LD scored lower than the JB, CU, AY, and OC. In addition, the CS scored lower than the LF and the LF scored lower than the OC. These data are similar to the pairwise difference findings in the previous analyses using nude displacement as the covariate and indicate the nature of the non-significant interaction. It is also apparent the covariate combination of breast circumference, chest circumference, chest depth and chest accounts for approximately the same amount of share variance ($\eta^2 = .03$) in this model as the single covariate of nude displacement accounted for in the previous model ($\eta^2 = .04$).

Insert Table 8 about here

Discussion

Displacement in the Nude Condition

The D cup size group displayed significantly more vertical displacement in the nude condition than either the A, B, or C cup size groups, and there were no other statistically significant differences among cup sizes. This finding supports the idea that excessive breast motion is a more serious problem for active women in the D cup size group, and that sports bra designed specifically for this (and larger) cup sizes is important.

Displacement Allowed by the Eight Bra Styles

The CS and LD bras demonstrated excellent low ratings for vertical displacement for the entire group and within all cup sizes wearing either the 7 or 8 styles. This was true when either nude displacement or the combination of breast circumference, chest circumference, chest depth or chest width were used as covariates. In the groups wearing 8 bras the OF bra also performed well, demonstrating low ratings in three (B, C, and C) cup sizes. A description of specific design features of these, and of the bras which performed poorly may help explain some of the reasons for performance.

First, the fabric of the CS bra is very firm and only slightly stretchy. The straps also allow minimal stretch. The waist-length design of the bra allows the bra to fit firmly around the torso without cutting in below the breasts, and provides support from both above and below the breasts. The design produces a rather flattened, rounded

silhouette, which serves to hold the breasts close to the body. The LD bra is also constructed of a very firm, barely stretchy fabric, and the double layer of material in the cup area provides additional support. Since the band below the breasts and the binding around the armholes are non-elastic, the only stretch comes from an elastic insert at the back of the bra and at the back ends of the straps. The LD bra is a firmer, even less "giving" design than the CS bra, and probably scored slightly less well on displacement because its rather pointed cup silhouette allows the tips of the breasts to move more.

The OF bra's design features that help control motion include molded, non-stretch cups, non-elastic straps which are connected almost directly to the cup, and a rounder contour that keeps the breasts relatively close to the body. The LF bra, which allowed less motion than the JB or OC (only in the D cup size) has similar design characteristics. However, the cups are set into a surrounding stretchy frame, which may keep the LF bra from controlling motion as effectively as the CS, LD, or OF.

Two of the bras that performed least well—the JB and the OC bras—are constructed of all-elastic fabric and straps. The CU bra, which also performed poorly (although somewhat better than the JB and OC bras), is also constructed of somewhat stretchy fabric, the straps are quite elastic, and the cups are surrounded by stretchy inserts. This degree of elasticity does not appear to provide the needed support, particularly for larger breasted women. The AY bra, while being constructed of rather firm fabric, may offer too little support

below the breasts, and has an excessively pointed silhouette which does not hold the breasts close to the body and allows unnecessary motion.

Suggestions for Future Research

During the process of analyzing the film, it became evident that there is a fair amount of lateral breast displacement occurring during exercise. In some cases, this lateral motion appeared to add significantly to the total length of the excursion of the breast with each stride, so that vertical displacement alone was perhaps not a valid measure of total breast motion. The extent of lateral motion seemed to be dependent upon the amount of shoulder rotation and the running style exhibited by each subject, as well as on breast size. Because of difficulties in distinguishing lateral breast displacement from shoulder rotation while observing from a single camera angle, no attempts were made to measure lateral displacement of total breast excursion. In future research, the distance of total breast excursion during exercise needs to be examined. Access to computer interfaced video equipment and to software for digitizing the information would make this type of analysis fairly straightforward. The use of two camera angles would enable the researcher to separate lateral displacement due to breast motion from shoulder rotation.

Another observation that resulted from viewing the films during the analysis procedure is that stride frequency seems to affect the amount of vertical displacement. Even though all Ss ran with the treadmill set at a given speed and grade during filming, the frequency

of their steps determined how far in the air they rose and fell with every stride. Large bounding strides appeared to increase the distance, speed and momentum of breast motion, and thereby increased the force with which the breast slapped against the chest wall. Quicker, smaller steps minimized the up and down movements of the breast. Informal observation of the differences in stride frequencies for the various cup size groups suggest that larger breasted women may have adapted a shorter stride so as to minimize breast motion and run more comfortably. In future research, stride frequency during the filming process needs to be standardized by the use of a metronome. This would assure greater accuracy in comparing both style and cupsize differences.

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Table 1

Anthropometric Characteristics of Subjects

	Entire Group	A Cup	B Cup	C Cup	D Cup
N	59	14	16	15	14
Height (cm)					
Mean	164.80	163.98	166.37	164.69	164.34
SD	6.96	4.57	7.72	7.45	7.77
Weight (kg)					
Mean	59.55	56.74	59.03	60.46	61.99
SD	7.01	6.14	6.89	7.19	7.41
Body Fat (%)					
Mean	24.46	22.01	24.01	26.36	25.39
SD	6.54	5.68	8.04	4.52	7.06
Chest Circ. (cm)					
Mean	78.21	77.34	78.13	77.04	80.40
SD	4.81	4.18	5.55	4.11	4.93
Breast Circ. (cm)					
Mean	88.48	84.93	87.09	87.99	94.16
SD	6.07	4.28	4.16	5.89	6.13
Chest Width (cm)					
Mean	28.62	27.69	28.36	28.44	30.03
SD	1.90	1.96	1.72	1.32	1.94
Chest Depth (cm)					
Mean	22.78	21.86	22.31	23.07	23.92
SD	2.13	2.76	1.64	1.83	1.81

Table 2
Survey Frequencies for Incidence of Breast Injuries,
Breast Pain and Sports Bra Usage

	Whole Group N=59	<u>Cup Size Groups</u>			
		A N=14	B N=16	C N=15	D N=14
Sports-related Breast Injury	9 (15.3%)	3	4	0	2
Exercise-related Breast Pain or Discomfort	33 (55.9%)	9	9	4	11
Previous Sports Bra Usage	18 (30.5%)	6	5	6	1

Figure 1

Design Features of Bras

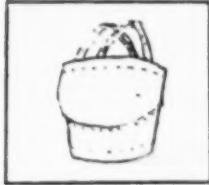
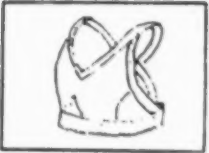
<u>Style & Price</u>	<u>Fabric</u>	<u>Features</u>
Elegant Support \$29.95	94% nylon, 6% spandex	No rigid fasteners Non-stretch cross straps Boned support from above the breast Snug fit to the waist Firm, thick fabric Custom sizes available from 30 A to 42 DD
		
Jogbra \$20.00	Cups: 46% cotton, 8% Lycra, 46% polyester Elastic: Lycra, nylon, polyester	No rigid fasteners Seams away from body Elastic cross straps Flat cut to compress breasts Wide elastic band below breasts Salt-resistant elastic Ventilation panel below breasts
		
Lady Duke \$18.95	Cups: 55% cotton, 45% polyester Elastic: 82% nylon 18% spandex	Firm fabric Non-stretch straps Seams away from body Non-elastic band below breasts Wide camisole back with 5 hooks Optional protective Ensolite pad inserts
		
Cupid \$7.50	Body: Cotton, polyester, spandex	Light mesh cup fabric Adjustable straps Stretch mesh inserts under breasts to keep bra in place
		

Figure 1 (continued)

Actively
Yours

\$21.50



Cups & Straps:
80% polyester
20% cotton
Mesh inserts:
100% nylon
Back: 42% nylon,
33% cotton
25% Lycra

Adjustable non-stretch
straps
Lowcut armholes
Mesh inserts above and
between cups
Polyester/cotton
blend cups

Olga's Christina
Sportsbra

\$22.00

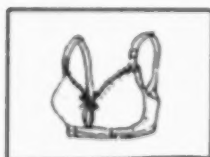


92% cotton,
8% Lycra

"Y-back" stretch straps
Inner molded stretch cup
Cotton encased elastic
band below breasts
No rigid fasteners

Olga's Freedom
Frontrunner

\$17.00



Cups:
65% cotton,
35% polyester
Back:
78% nylon,
22% spandex

Molded, poly-cotton mesh
non-stretch cups
Adjustable non-stretch
straps
Ventilation slit between
cups
Covered inside seams

Lily of France

\$15.00



Cups:
82% polyester,
12% cotton,
6% spandex
Elastic:
83% nylon
17% spandex

Smooth, molded cups
Lace inserts around
cups for ventilation
Adjustable non-stretch
strap
Covered inside seams
Strap placement set
close in back to
straps up on shoulders

Table 3

One-Way ANOVA Summary Table for Nude Breast
Displacement and Analysis of Pairwise Differences
for Nude Breast Displacement (LSD Method)

ANOVA Summary Table

Source of Variation	df	MS	<u>F</u>	p Level	Eta ²
Between Cupsize Groups	3	14.02	4.73	0.005	.21
Within Groups (Error)	55	3.03			
Total	58	17.09			

Pairwise Differences

Mean (cm)	SD	Cup Size Group	A	B	C	D
5.76	1.82	A				
5.99	1.92	B				
6.55	1.76	C				
7.98	1.30	D	*	*	*	

*Denotes pairs of groups significantly different, $p < .05$. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 4
ANCOVA Summary Table for Vertical Displacement for
the A, B, C, and D Cup Size Groups Wearing Seven
Styles and Analysis of Pairwise Differences

ANCOVA Summary Table $R^2 = .62$

Source of Variation	df	MS	F	p Level	Eta ²
<u>Covariate</u>					
Nude Displacement	1	46.81	35.59	0.000	.04
<u>Main Effect</u>					
Cupsize (S)	3	16.06	2.53	0.067	.05
Person/Cupsize (P) [Error A]	55	6.36	4.70	0.000	.32
Style of Bra (B)	6	25.66	18.96	0.000	.14
Cupsize x Style	18	1.79	1.32	0.170	.03
Style x Person/ Cupsize [Error B]	330	1.35			.41
TOTAL	413	93.03			

Pairwise Differences*

Adjusted Mean	SD	Style	CS	JB	LD	CU	AY	OC	LF
1.67	0.15	CS		*		*	*	*	*
1.99	0.15	LD		*		*	*	*	*
3.02	0.15	JB							
3.05	0.15	LF							
3.11	0.15	AY							
3.30	0.15	CU							
3.30	0.15	OC							

*Denotes pairs of groups significantly different, $p < .05$. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 5
ANCOVA Summary Table for Vertical Displacement for
the A, B, C, and D Cup Size Groups Wearing Eight
Styles and Analysis of Pairwise Differences

ANCOVA Summary Table $R^2 = .70$

Source of Variation	df	MS	F	p Level	Eta ²
<u>Covariate</u>					
Nude Displacement	1	53.29	56.43	0.000	.06
<u>Main Effect</u>					
Cupsize (S)	2	13.49	1.82	0.175	.03
Person/Cupsize (P)					
[Error A]	55	7.41	7.84	0.000	.44
Style of Bra (B)	7	21.17	22.42	0.000	.16
Cupsize x Style	14	1.26	1.33	0.189	.02
Style x Person/ Cupsize [Error B]	294	0.94			.30
TOTAL	373	97.56			

Pairwise Differences*

Adjusted Mean	SD	Style	CS	JB	LD	CU	AY	OC	OF	LF
1.67	0.15	CS		*		*	*	*	*	*
1.99	0.15	LD		*		*	*	*	*	*
2.77	0.15	OF		*		*	*	*	*	*
3.02	0.15	JB								
3.05	0.15	LF						*		
3.11	0.15	OC								
3.30	0.15	CU								
3.30	0.15	OC								

*Denotes pairs of groups significantly different, $p < .05$. In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column.

Table 6
Analysis of Pairwise Differences for Vertical
Displacement Within Cup Size

A Cup (In seven styles)

Adjusted Mean	SD	Style	CS	JB	LD	CU	AY	OC	LF
1.34	.31	LD				*	*		*
1.70	.31	CS				*			*
2.14	.31	AY							
2.19	.31	JB							
2.33	.31	OC							
2.63	.31	LF							
2.96	.31	CU							

B Cup (In eight styles)

Adjusted Mean	SD	Style	CS	JB	LD	CU	AY	OC	OF	LF
1.38	.29	CS		*		*	*	*	*	*
1.93	.29	LD				*	*	*		
2.31	.29	OF								
2.41	.29	JB								
2.46	.29	LF								
2.77	.29	OC								
2.77	.29	AY								
2.89	.29	CU								

C Cup (In eight styles)

1.53	.30	CS		*		*	*	*	*	*
1.87	.30	LD		*		*	*	*	*	*
2.57	.30	OF					*	*		*
2.99	.30	JB								
3.07	.30	CU								
3.35	.30	AY								
3.47	.30	LF								
3.51	.30	OC								

D Cup (In eight styles)

2.08	.31	CS		*		*	*	*	*	*
2.85	.31	LD		*		*	*	*		*
3.42	.31	OF				*	*	*		
3.64	.31	LF		*				*		
4.16	.31	AY								
4.27	.31	CU								
4.49	.31	JB								
4.62	.31	OC								

*Denotes pairs of groups significantly different, $p < .05$. Note: In each pairwise case, the style in the horizontal row scored significantly lower in displacement than the style in the column.

Table 7
ANCOVA Summary Table for Vertical Displacement for
the A, B, C, and D Cup Size Groups Wearing Seven
Styles and Analysis of Pairwise Differences

ANCOVA Summary Table $R^2 = .62$

Source of Variation	df	MS	F	p Level	Eta ²
<u>Covariate</u>					
Breast Circumference	1	1.03	.77	.38	.00
Chest Circumference	1	14.26	10.54	.00	.01
Chest Width	1	7.39	5.46	.02	.01
Chest Depth	1	5.21	3.85	.05	.01
<u>Main Effect</u>					
Cupsize (S)	3	15.64	2.30	.09	.05
Person/Cupsize (P) [Error A]	51	6.79	5.02	.000	.33
Style of Bra (B)	6	25.66	18.96	.000	.15
Cupsize x Style	18	1.79	1.32	.17	.03
Style x Person/ Cupsize [Error B]	330	1.35			.42
TOTAL	412				

Pairwise Differences*

Adjusted Mean	SD	Style	CS	JB	LD	CU	AY	OC	LF
1.67	0.15	CS		*		*	*	*	*
1.99	0.15	LD		*		*	*	*	*
3.01	0.15	JB							
3.05	0.15	LF							
3.10	0.15	AY							
3.30	0.15	CU							
3.30	0.15	OC							

*In each pairwise case, the style in the horizontal row scored significantly lower on displacement than the style in the column, ($p < .05$).

Table 8
Analysis of Pairwise Differences for Vertical Displacement
Within Cup Size For Seven Styles (ANCOVA Included 4 Covariates)

A Cup

Mean (cm)	SD	Style	CS	JB	LD	CU	AY	OC	LF
2.70	.74	LD				*		*	*
3.06	.74	CS				*			*
3.51	.74	AY							
3.55	.74	JB							
3.70	.74	OC							
4.00	.74	LF							
4.33	.74	CU							

B Cup

2.40	.54	CS		*		*	*	*	*
2.94	.54	LD				*	*	*	
3.43	.54	JB							
3.48	.54	LF							
3.78	.54	OC							
3.79	.54	AY							
3.91	.54	CU							

C Cup

-.46	.78	CS		*		*	*	*	*
-.12	.78	LD		*		*	*	*	*
.10	.78	JB							
1.08	.78	CY							
1.36	.78	AY							
1.48	.78	LF							
1.52	.78	OC							

D Cup

1.67	.58	CS		*		*	*	*	*
2.45	.58	LD		*		*	*	*	
3.24	.58	LF						*	
3.76	.58	AY							
3.87	.58	CU							
4.07	.58	JB							
4.22	.58	OC							

*Denotes pairs of groups significantly different, $p < .05$. Note: In each pairwise case, the style in the horizontal row scored significantly lower in displacement than the style in the column.